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The Development and Sub-division of the Tertiary system in Burma, by DR. FRITZ NOETLING, F.G.S., *Palæontologist, Geological Survey of India.* (With a map).

HISTORICAL SUMMARY.

In the following summary of the former geological work done in Burma, I shall restrict myself to a review of those papers which deal with Lower and Upper Burma, that is to say with that part of Further India which is situated between the Shan hills in the east and the Arrakan Yoma in the west, and which represents, properly speaking, the country of Burma. I shall therefore disregard all papers dealing with the geology of Tenasserim and Arrakan.

Although, since the end of the last century, Burma has been visited by numerous travellers, who have related their experiences in various publications, the outcome of these travels has been very poor, with regard to the geological knowledge of the country. This is the more remarkable in that Burma has been famous for its mineral wealth, and nearly every traveller had in view the enormous mineral resources of the country. The meagre results are doubtless due to the want of geological training of most of the travellers, and this in its turn might again account for the legend of the enormous mineral wealth of Burma.

Among the names of those who wrote on geological subjects connected with Burma, previous to the researches of Dr. Blanford, Mr. Fedden, and Mr. Theobald, two only deserve mention, but they shine with the greater brilliancy amongst the numerous amateur attempts to deal with the geology of Burma: these are the names of Dr. Buckland and Dr. Oldham.

As early as 1829, from specimens which had been collected by Mr. Crawford in Upper Burma, and brought by him to England, Dr. Buckland recognised the following formations :—[1]

1. Alluvium.
2. Diluvium.
3. Fresh-water marl.
4. London-clay and calcaire grossier.
5. Plastic clay with its sands and gravel.
6. Transition limestone.
7. Grauwacke.
8. Primitive rocks, marble, mica slate.

Considering the state of geological science at that period, it is astonishing how accurately Dr. Buckland has recognized the formations which occur in Burma. It is unnecessary here to deal with his groups 6 and 8, as, for the purposes of this paper, we are mainly interested in the younger formations; but, with regard to these, it must be said that Dr. Buckland has already recognized some of the most important sub-divisions of the Burma tertiaries. Had he not been led by a mistaken inference to suppose that the fossil bones were also found in diluvial beds in Burma, he would, in fact, already have fixed the great divisions into which the tertiary rocks of Burma can be divided. If we substitute "Upper Tertiary" for the word "Diluvium," or if we keep in mind the fact that his diluvium really represents tertiary strata, we shall see that Dr. Buckland has already sketched in

[1] Transact. Geolog. Soc., 2nd series, 1829, vol. ii, p. 377.

broad outlines the sub-division of a part of the tertiary system in Burma, which still holds good at the present day. His diluvium and fresh-water marl represent the two groups into which I have divided the Burma strata, *viz.*, the upper ossiferous Irrawaddi division and the Yenangyoung division; the "London clay" represents the Pegu division, as is unmistakeably proved by the list of fossils, and if we unite his group No. 5 with the London clay, the three upper divisions of the Burma tertiaries are at once recognized.

That the nummulitic formation was overlooked is easily explained, when we remember that its outcrops are only visible far away inland at places that Mr. Crawford could not visit.

Dr. Buckland however, was, mistaken in identifying a piece of rock from Minlindoung near Yenangyoung with the "Grauwacke" formation of Europe, as, no such strata occur within the neighbourhood of Yenangyoung, particularly at the said hill, which is entirely built up of tertiary strata.

It is much to be regretted that no opportunity for the study of the geological formations of Burma was afforded to Dr. Oldham, beyond those casual visits ashore, when the necessary delays of a river journey in those days stopped the progress of the mission to Ava. Otherwise that acute and careful observer would have been able to give us a more detailed account of the geology of Burma, than that to be found in his notes on the "Geological features of the banks of the Irrawaddi, etc."[1] As it is, Dr. Oldham was obliged to give his observations in the form of a narrative, which, although full of lucid and detailed observations, renders it very difficult to follow the author's opinion as to the division of the groups he has noticed. Dr. Oldham expresses his opinion that the rocks of the area within which the oilfields of Yenangyoung are situated belong to the tertiary system, but probably owing to lack of time he does not go into the subject of the division or correlation of these tertiary beds.

It was not until after the researches of Dr. Blandford, Mr. Fedden and Mr Theobald in Lower Burma, that anything like a sub-division of the tertiary system was attempted. Mr. Theobald, who has embodied the results of his own researches and those of his two colleagues in his interesting memoir on the Geology of Pegu,[2] proposes the following sub-division for the Tertiary rocks of Lower Burma :—

Younger Tertiary	{	Fossilwood group. Pegu group.
Older Tertiary .		Nummulitic group.

Of these the Nummulitic group is considered as correlative with the Eocene of Europe, while the Pegu group represents the Miocene; the "Fossil wood group" represents the Pliocene, but Mr. Theobald leaves it an open question as to whether strata of probably Post-Pliocene age are not perhaps also represented in the "Fossil wood group."

We shall presently see that Mr. Theobald has quite correctly recognized the principal divisions of the tertiary rocks in Burma, and although he may have failed in the accurate delimitation of these groups, it is well to state at once that these three sub-divisions are also recognizable in Upper Burma. Where Mr. Theobald's division is chiefly defective is with regard to the Lower Tertiary. Subsequent researches have proved that the "Axial group" (which Mr. Theobald has, on the

[1] Yule: Narrative of a mission to the Court of Ava in 1855. Appendix A, *p.* 307.

[2] Memoirs of the Geological Survey of India, Vol. X.

strength of a misinterpreted fossil, regarded as of Triassic age) must either be included in the tertiary system, of which it represents the lowest division; or might probably form the highest beds of the cretaceous system. Now, anyone acquainted with the country in which the "Axial" formation is chiefly developed, will readily understand the difficulty of accurate observation in such a jungly country as the Arrakan Yoma. In fact, the question of the age of the "Axial group" is not quite settled yet. All we know is that it does not belong to the Triassic system: this may be considered as certain, but whether it represents the lowest tertiary or the topmost cretaceous strata, is a question which still requires careful investigation. In the following pages I have provisionally accepted the view of the tertiary age of the "Axial group," but I wish to state at once that by no means do I consider this question as decided.

The same applies to Mr. Theobald's Negrais rocks, which are probably only metamorphosed Eocene beds. But not having seen these beds I am unable to express my views as to their appearance.

Mr. Theobald has sub-divided both the Pegu and the Fossil wood groups, the first into two, the second into three sub-divisions; but none of these can, to judge from our present experience, claim more than a local importance.

In the following division of the Tertiary rocks in Burma, I have attempted to combine Mr. Theobald's observations with my own in Upper Burma, and I trust that I may have at least succeeded in fixing the outlines of groups therein represented. But years and years of patient labour will elapse before we can arrive at anything like a definite idea of the finer details. If in the following pages the Upper Tertiary is more explicitly dealt with, this is not because it is of much more importance than the Lower Tertiary, but because my work brought me chiefly in touch with the Upper Tertiary.

Division of the Tertiary Rocks of Upper Burma.

Wherever a complete series of the tertiary beds is developed in Upper Burma, we can, with the greatest ease, recognize and distinguish two groups, which differ widely in the character of the fauna they contain.

The lower group is characterised by a *marine* fauna, which is entirely free from any terrestrial or fluviatile elements in the lower part, but locally shows a slight foreign element by the admixture of rolled fragments of terrestrial animals in its upper beds.

The upper group contains chiefly remains of *terrestrial* animals, mixed with such forms as, according to the habits of their present representatives, must have led an *aquatic* life.

Hand in hand with this wide difference in the palæontological characters goes a distinct change in the features of the sediments. Dark bluish and grey colours characterise those of the lower, and yellow, olive-green and red those of the upper group.

Notwithstanding this wide difference between the two groups, it seems as if the upper rests conformably on the lower, although there exist no passage beds between the two,—a fact which must not be overlooked. I therefore divide the Burma tertiaries into two sub-divisions, *viz*:—

2. Upper Tertiaries or Burma series.
1. Lower Tertiaries or Arrakan series.

For the lower division I suggest the name of *Arrakan series*, owing to its chief development in the Arrakan Yoma; the upper one may be called the *Burma series*, because it is chiefly developed in the broad depression between Arrakan Yoma in the west and Shan hills in the east, which forms the country of Burma proper.

I. Arrakan Series.

The Arrakan series can again be sub-divided into three groups, which palæontologically, as well as lithologically exhibit considerable differences.

The lowest of these groups is very little known; in fact, we may say we know nothing with regard to its palæontological features.

The middle group is characterised by the abundance of *Nummulites*; while the chief feature of the upper group is the total absence of this genus. Lithologically the two lower groups are characterised by shales and limestones, while, in the upper, sandstones predominate to the nearly total exclusion of other rocks. For the lowest group I suggest the name *Chin division*, while for the middle and upper one Mr. Theobald's names *Nummulitic division* and *Pegu division* may be retained.

1. The Chin Division.

Only the bare outlines of the features of this group can be laid down up to the present, it being one of the least known members of the Burma tertiaries. I am nearly certain that subsequent discoveries will essentially modify the views here expressed. So far as I am able to say for the present, the following are the features of this group.

Lithologically, flysch-like shales, and hard limestones are the predominating rocks. It seems as if the shales almost exclusively occupied the lower part of the group, and were followed by the limestones.

Not even the approximate thickness of the shales can be given, but it may safely be supposed that it was considerable. So far as it is known, the central part of the Arrakan Yoma is chiefly built up of these shales, where they form, particularly in the Chin country, numerous parallel ridges rising to over 7,000 feet above sea level. No fossils have been discovered for the present in these shales, but this by no means proves that they are unfossiliferous.

Mr. Theobald's so-called "Axial group" of the southern part of the Arrakan Yoma, which he considered of Triassic age, represents in a broad sense these shales, and it is chiefly due to the observations of Mr. Griesbach, who examined a part of the Arrakan Yoma, where the Axial group was supposed to be present, that we know that it belongs to the tertiary system, and probably forms its lowest part. It requires, however, a long and careful examination before more can be said about the Chin-shales, an examination which will be extremely difficult in a country like the Arrakan Yoma, which is covered with almost impenetrable virgin forest.

2. The Nummulitic Division.

We know a little more about the middle part of the Arrakan series, although this knowledge is very scanty. According to Mr. Theobald, the total thickness of the *Nummulitic* or *Eocene group*, as he calls this subdivision, is 1,223 feet, but to judge from the table given on page 100 of his Memoir, it is quite certain that he has included

at least 227 feet more, probably about 500 feet of shales, which probably should be included in the Chin shales. However, this is a matter which can only be decided by actual observation in the field.

According to Mr. Theobald, the lower part of the nummulitic division consists of shales and sandstones, occasionally fossiliferous, capped by a bed of highly fossiliferous nummulitic limestone, of only 10 feet in thickness.

Although I have no doubt as to the correctness of this observation, it is quite certain that in a northern direction the limestone increases in thickness and importance, at the expense of the arenaceous beds. However, this is a matter which must be left to the future to decide.

The fauna discovered in this group, for which we may for the present retain the name *Nummulitic* division, is a rich one, but we know absolutely nothing as to its relationship, because owing to more pressing work, none of my predecessors have undertaken the task of studying it. All that we know at present is that it contains numerous species of the genus *Nummulites*, and, in a bed which most probably belongs to the upper part of the series, the well-known Eocene species, *Velates schmideliana*, Chem. sp. As I have pointed out in the paper, in which I described the occurrence of this species, [1] we may infer from the limited vertical distribution of this species, not only in Europe, but also in Western India, that the stratum in which it was found in Burma belongs to the Eocene system, and must most probably be considered as correlative to the Khirthar group of Western India.

The occurrence of the genus *Nummulites* together with the typical Eocene species, *Velates schmideliana*, Chemn. sp., leaves, therefore, not the slightest doubt that this part of the Arrakan series must be considered as of Eocene age, having in the Khirthar group its correlative in Western India. The lower Tertiaries would therefore be subdivided as follows:—

1. Upper Eocene: *Nummulitic* division.
   Shales and limestones containing a rich fauna of typical eocene forms,
2. Lower Eocene (?): *Chin shales.*
   Shales predominate and have not yielded any fossils up to the present time.

As regards the distribution of the two sub-divisions of the Eocene rocks in Burma it is practically such that the Chin-shales cover a much wider area than the nummulitic division, which, so far as our present knowledge goes, forms only a comparatively narrow band along the outskirts of the Arrakan Yoma.

In conclusion, however, I wish particularly to point out that all that I have said above regarding the subdivision of the Lower Arrakan series must be considered as preliminary. I myself have only very rarely had occasion to observe it, and the above remarks are chiefly based on Mr. Theobald's observations, as they appear in the light of the later researches, particularly those by Mr. Griesbach and myself. I need hardly add that it will require years and years of careful labour in the field, as well as in the museum, before we arrive at anything like a clear conception of the development of the Eocene rocks in Burma.

3. The Pegu division.

The name "Pegu group" was proposed by Mr. Theobald "for a very important

[1] Records, Geological Survey of India, 1894, vol. xxvii, page 103.

series of beds intervening between the Eocene or nummulitic division on the one hand, and the fossil wood division on the other."

The above definition of the Pegu division would be a very clear and concise one, if Mr. Theobald had more accurately defined the lower boundary of his "fossil wood group." As it is, the boundaries of the "fossil wood group" are very uncertain and thus the upper limit of the Pegu division is very ill-defined.

I propose to apply the name of Pegu division to that series of beds, which are between the Eocene rocks—characterised by their peculiar marine fauna—and the Irrawaddi division—characterised by its peculiar terrestrial fauna.

In the above definition, the Pegu division constitutes a very well circumscribed series of beds, which are characterised as follows :—

The fauna is of a marine type throughout, but the genus Nummulites is entirely absent. Towards the upper limit rolled fragments of terrestrial animals are, in one place at least, mixed with a purely marine fauna; lithologically, sandstones of pepper and salt colour are predominant, while blue clays are more subordinate.

The above features are so well defined wherever the Pegu-division occurs in Upper Burma, that it is not easy to mistake it, although it varies locally a good deal, as may be expected in a series chiefly composed of sandstones and clays; so that it is frequently very difficult to correlate the local developments of the Pegu division at different localities in Burma. In fact the local developments differ so widely that even at places close to each other, such as Minbu, Yenangyoung, Yenangyat it is extremely difficult, if not impossible, to correlate the single strata composing the sections at the different localities. The difficulty increases of course with the distance, and years will lapse before the relations of this division in Lower and Upper Burma are sufficiently studied. We know, however, for the present enough of the development of this group to enable us to give some more details. The Pegu division may be conveniently separated into two sub-divisions, for the lower of which I propose the name of *Prome stage* owing to its chief development in the neighbourhood of that town, while for the upper one the name of *Yenangyoung stage* is suggested.

A.—Prome Stage.

a. Thickness.

Mr. Theobald describes a section of this stage near Prome, measuring 1,950 feet in thickness; but he adds that this apparently does not represent the total thickness. Although, if I interpret his views correctly, he does not think that the total thickness is very much greater.

At Yenangyoung the drill has gone through rocks of the Prome stage up to a depth of 1,000 feet without apparently touching their base.

At Yenangyat it is known partly by surface outcrops, partly by borings, to have a thickness of not less than 1,100 feet.

On the right bank of the Chindwin between the Kale and Yu river, I estimated its thickness at about 5,100 feet. In this part of the country I must have been pretty close to the base, although the actual contact between the upper Eocene and the lower beds of the Prome stage was not observed, but numerous pebbles containing Eocene fossils indicated the proximity of the Eocene beds.

If therefore we estimate the total thickness of the Prome stage at something like 5,000 feet, I think we shall not be very far off the mark

b. Lithological characters.

The chief constituents of the Prome stage are sandstones and clays, the latter are however much subordinate to the former; still more subordinate are coal seams and ferruginous clays; locally the sandstones contain petroleum, and, at isolated places, the fossil resin, burmite. The sandstone is very uniform in character, it is finely grained, of a greyish colour, which may best be styled "pepper and salt colour." Sometimes the sandstone is very soft, other beds are more siliceous, and therefore harder. When exposed, these beds disintegrate into rather regular lumps, which retain for a long time their original position, before they fall to pieces. Such beds which resemble the pavement, may frequently be seen between Thayetmyo and Prome, or on the Upper Chindwin.

The clay is also of very uniform character, being generally a very tough clunch of bluish colour.

Sandstone and clay alternate in beds of various thickness; frequently, as for instance near Yenangyoung, beds of clay as thin as paper may alternate with similar beds of sandstone, while at other places, as for instance in the Upper Chindwin district, the sandstone forms a continuous bed of several hundred feet in thickness. The clay beds may also attain a considerable thickness, but I never found that they equalled the sandstone in this respect.

The coal seams are generally of small thickness, the thickest known to me is a seam of 10 feet, cropping out in the ravine of the Nantahinchoung in the Upper Chindwin district; generally they are between 1 and 2 feet in thickness. It would exceed the limits of this paper were I to dwell in detail on the occurence of the coal in Upper and Lower Burma; those interested in its occurence will find ample information in the papers cited below.[1]

It seems, however, that in the Chindwin district the coal seams are restricted to the lower part of the Prome stage, but to judge from other localities such as Kabwet, Wuntho or Thayetmyo some seams of inferior quality also occur in the upper parts.

As the occurrence of the petroleum will be dealt with in a special memoir, which will shortly be published, it is needless to go into details. All that may be said is, that it appears that the petroleum chiefly occurs in the upper parts of the Prome

[1] Oldham: Memorandum on the coal found near Thayetmyo on the Irrawaddi river Selections from the Records of the Government of India, Home Department No. X, page 99, 1856. Reprinted in papers on Burma, issued by the Geological Survey.

Oldham, in Yule's Narrative of a Mission to the Court of Ava, Appendix A., page 330.

Jones: Notes on Upper Burma: Records of the Geological Survey of India, Vol. XX, Part II, 1887, page 185.

Noetling: Memoir on the Upper Chindwin Coal-fields, 1889.

Noetling: Report on the coal-fields in the Northern Shan States: Records of the Geological Survey of India, 1891, Vol. XXIV, page 99.

Noetling: Note on the Geology of Wuntho in Upper Burma: Records, Geological Survey of India, Vol. XXVII, page 119.

stage, but that it is unquestionable that small quantities are also found in the lower parts.

The occurrence of the fossil resin, burmite, the famous amber of Burma, has been described by me in a special paper.[1] Dr. Helm [2] has devoted two papers to the chemical properties of this fossil resin, which, according to him, is distinctly different from the real amber or succinite.[3]

c. Palæontological characters.

Although the rich fauna which Messrs. Theobald and Fedden collected in the Pegu division of Lower Burma still waits to be described, the examination of the fauna discovered in the petroleum-bearing strata of Yenangyat has shed so much light on the age of the Prome stage that we can now classify it definitely in the sequence of the tertiary beds without being obliged to have recourse to an indirect method. The information recently obtained by the deep borings at Yenangyat, has proved that the fauna which I have described [4] from this place comes from the petroliferous sandstone at the top of the Prome stage. The following species have been observed :—

1. *Paracyathus caeruleus*, Duncan.
2. *Eupsammia regalis*, Alcock.
3. *Ostrea sp.*
4. *Pecten cf. favrei*, d'Arch. & Haime.
5. *Daphoderma cœlata*, Reeve.
6. *Nucula alcocki* Noetling.
7. *Astarte* (?) *dubia*, Noetling.
8. *Venus cf. scalaris*, Bronn.
9. *Tellina* (*Tellinella*) *hilli*, Noetling.
10. *Tellina kingi*, Noetling.
11. *Solen sp.*
12. *Corbula harpa*, d'Arch. & Haime.[5]

[1] On the occurrence of Burmite in Upper Burma : Records, Geological Survey of India, 1893, vol. xxvi, page 31.

[2] Note on a new fossil amber-like resin occurring in Burma : Records, Geological Survey of India, 1892, vol. xxv, page 180.

Further Note on Burmite, a new amber-like fossil resin from Upper Burma, Records, Geological Survey of India, 1893, vol. xxvi, page 61.

[3] It may here not be quite out of place to correct a mistake with regard to the age of certain coal seams occurring in Tenasserim. Mr. Oldham in the Manual of India, 2nd edition, page 297, expresses his view, that as the coal contains small nodules of a resinous mineral like amber, these coal seams were of cretaceous age, because in the Assam hills the mineral resin is characteristic of the cretaceous coals. If any inference regarding the age were admissible from the association of fossil resin and coal, it could only be one, and that is that the coal seams are of miocene age, because everywhere in Upper Burma the fossil resin is found in strata belonging to the Prome stage, which is of distinctly miocene age.

[4] Memoirs, Geological Survey of India, vol. XVII, Part I.

[5] It may be remarked here that the species which I determined as *Corbula harpa* d'Archiac and Haime is really different from that species, although this could not be recognised at the time owing to the rather deficient figure of Messrs. d'Archiac and Haime. The recent examination of the *Corbula harpa* d'Arch. and Haime from Sind has proved that notwithstanding the great similarity of the right valve, it materially differs from the Burma species by the sculpture of the left valve ; *Corbula harpa* d'Arch. and Haime from Burma must therefore be cancelled, and a new name substituted for it. My remarks on page 4 of the abovenamed memoir, have therefore been fully borne out by the facts, and one anomaly of the otherwise truly miocene fauna has disappeared.

13. *Trochus buddha*, Noetling.
14. *Trochus blanfordi*, Noetling.
15. *Solarium affine*, Sow.
16. *Discohelix minuta*, Noetling.
17. *Turritella affinis*, d'Arch. & Haime.
18. *Siliquaria sp.*
19. *Calyptraea rugosa*, Noetling.
20. *Natica obscura*, Sow.
21. *Natica callosa*, Sow.
22. *Sigaretus cf. bicostatus*, Sow.
23. *Aporrhais* sp.
24. *Cypræa granti*, d'Arch. & Haime.
25. *Trivia smithi*, K. Martin.
26. *Cassidaria dubia*, Noetling.
27. *Cassidaria minbuensis*, Noetling.
28. *Ficula theobaldi*, Noetling.
29. *Triton pardalis*, Noetling.
30. *Ranella tuberculatis*, Lamark.
31. *Nassa cautleyi*, d'Arch. & Haime.
32. *Clavella djocdjocartæ*, K. Martin.
33. *Fasciolaria nodoulsa*, Sowerby.
34. *Fasciolaria feddeni*, Noetling.
35. *Murex* (*Muricidea*) sp.
36. *Murex tschihatscheffi*, d'Arch. & Haime.
37. *Murex arrakanensis*, Noetling.
38. *Voluta dentata*, Sowerby.
39. *Oliva djocdjocartæ*, K. Martin.
40. *Cancellaria cancellata*, Lam.
41. *Rapana* sp.
42. *Terebra fuscata*, Brocchi.
43. *Pleurotoma* (*Drillia*) *interrupta*, Lamark.
44. *Pleurotoma yenanensis*, Noetling.
45. *Conus* (*Rhizoconus*) *mallacanus*, Hwass.
46. *Conus* (*Leptoconus*) *marginatus*, Sowerby.
47. *Balanus sublaevis*, Sowerby.
48. *Callianassa* sp.
49. *Pagurus* sp.
50. *Lamna* sp.
51. *Galeocerdo* sp.
52. *Carcharias* (*Prionodon*) sp.

Out of a total of 52 species, 48 were specifically determined, but among these there are three species which could only be, with some doubt, referred to previously known species. There remain therefore 38 species, which are sufficiently well determined to allow of geological conclusions being drawn from them. Out of these 38 species, 15 have been recognized as new, while the balance of 23 species could be identified with species previously described, but as the species referred to *Corbula harpa*, from western India, cannot be considered as identical with this species, the figures therefore now stand as follows :—

New species . . .	16
Previously described species	22

The geological distribution of these 22 species is as follows :—

Recent, but not previously known in fossil state.

1. *Paracyathus cæruleus*, Duncan.
2. *Eupsammia regalis*, Alcock.

Nari group—

1. *Daphoderma cælata*, Reeve (*Arca burnesi*, d'Arch, and Haime).
2. *Solarium affine*, Sowerby.
3. *Turritella affinis*, Sow.
4. *Cypræa granti*, d'Arch. & Haime.
5. *Voluta dentata*, Sowerby.

Gaj group—

1. *Daphoderma cælata*, Reeve (*Arca burnesi*, d'Arch. & Haime).
2. *Natica obcsura*, Sow.
3. *Nassa cautleyi*, d'Arch. & Haime.
4. *Balanus sublævis*, Sow.

Older Tertiary—

1. *Daphoderma cælata*, Reeve.
2. *Fasciolaria nodulosa* Sowerby.

Of uncertain horizon are—

1. *Natica callosa*, Sowerby.
2. *Murex tschihatscheffi*, d'Arch. & Haime.
3. *Conus* (*Leptoconus*) *marginatus*, Sow.

In the Miocene of Java have been found—

1. *Trivia smithi*, K. Martin.
2. *Clavella djocdjocartæ*, K. Martin.
3. *Oliva djocdjocartæ*, K. Martin.
4. *Cancellaria cancellata*, Lam.
5. *Pleurotoma interrupta*, Lam.
6. *Conus* (*Rhizoconus*) *mallacanus*, Hwass.

From the above list it is evident that the fauna cannot be older than of Miocene age : only two species could be identified, which occur in the older tertiary beds of India : one of these, however, also ascends into higher groups, in fact, it is still living in the Indian Ocean. The geological horizon of three species is unknown, and we may therefore disregard them for the moment. Out of the remaining species—

Two are recent and not previously known in a fossil state.
Five range from the Miocene to the present day.
Three have been found in the Miocene of Java.
Four have been found in the Nari group of Western India.
Three have been found in the Gaj group of Western India.

As out of a total of 17 species, 7, that is to say nearly 50% are still living, we are therefore justified in assuming a miocene age for the beds which have yielded this fauna. It only remains to be seen whether the fauna bears a greater resemblance to the Gaj or to the Nari group of Western India. The evidence in this regard is very meagre, in fact it would be rather rash to form a final conclusion, but from the fact that the species from Java have been found in beds which are considered as of the same age as the Gaj group, I feel inclined to consider the fauna of the Prome stage as correlative to the Gaj group of Western India.

d. Facial development of the Prome stage.

In studying the development of this stage, particularly in Upper Burma, it is at once obvious that, notwithstanding the purely marine character of the fauna, some beds, which must be considered as homotaxial to the former, were either deposited in estuaries or at no great distance from the coast.

For instance, at Yenangyoung, a well, which had reached a depth of 156 feet from the surface, and which had, in the light of the information recently obtained, passed through the 1st and 2nd petroliferous sands, a highly fossiliferous conglomerate of about 6 inches in thickness was discovered in which I collected the following species :—

1. *Corallium, gen. div*; one closely related to *Paracyathus cæruleus, Dunc.*
2. *Teredo* sp.
3. *Venus* sp.
4. *Cardium* sp.
5. *Arca* sp.
6. *Pecten* cf. *favrei*, d'Arch & Haime.
7. *Gastropoda, gen. div.*

The invertebrata are all very ill-preserved, in fact they are either only casts or moulds, the calcareous substance of the shell being entirely destroyed by sulphuric acid, which is represented by a large quantity of iron pyrites. The latter makes the preservation of these fossils almost impossible: notwithstanding repeated coatings of varnish, they have, in the damp climate of Calcutta, almost entirely crumbled to pieces with considerable efflorescence. The vertebrata have yielded the following list :—

1. *Teleostei* gen. div.
2. *Myliobatis* sp.
3. *Odontaspis* sp.
4. *Carcharias* sp.
5. *Chelonian* bones.
6. *Crocodilis* sp.
7. *Antelope* sp. (?)
8. *Anthracotherium silistrense.*
9. *Rhinoceros* or *Hippopotamus* sp.

Besides the abovenamed forms which could be recognized with certainty, the conglomerate contained numerous fragments of bones, which have been too much rolled to be determined. The chief interest however rests with the fact, that fragments of terrestrial and estuarine forms are mixed with a purely marine fauna, and that such a strangely composed fauna has been found in strata between the 2nd and 3rd oil-sand at Yenangyoung.

On the other hand, the petroliferous sand of Yenangyat, which is perhaps a little higher in the series, has yielded the purely marine fauna above described.

In the Upper Chindwin district the coal-seams in the lower part of the Pegu division apparently indicate an estuarine, or at least a littoral deposit, while further south near Thayetmyo, a purely marine fauna is found in the lower portion of the Prome stage. It seems to me, therefore, that not only are beds, which are undoubtedly homotaxial, partly marine and partly of littoral or of estuarine character, but that also owing to local oscillations these changes take place in a vertical direction. On the whole it may, however, be said that the marine character is more pronounced

in Lower Burma, while the littoral or estuarine formation prevails in Upper Burma. This view, however, by no means affects the opinion expressed above as to the wide difference between the fauna of the Prome stage and that of the Irrawaddi division, nor does it modify the conclusions based thereon with regard to the sub-division of the Burma tertiaries.

e. Sub-division of the Prome stage.

It is obvious that, under the circumstances above described, a general sub-division of the Prome stage is extremely difficult, and that those attempts, which have so far been made by Mr. Theobald in Lower Burma, and by myself in the Upper Chindwin district, are of purely local value, hardly holding good for more than a few miles around the locality for which they were made.

Under these circumstances it would be superfluous to repeat them here. All that can be said is that, perhaps, after years of careful study, and after an exhaustive examination of the fauna, and a most careful determination of the fossiliferous horizons in the sequence of the series, it will, perhaps, be possible to arrive at a general sub-division of the Prome stage; for the present we must be satisfied with local sub-divisions, without making any attempt at correlating their individual members.

B.—The Yenangyoung stage.

A marked lithological difference distinguishes the overlying series of beds from the Prome stage. No sharper boundary can be imagined than the contrast between the bluish tinges of the Prome stage, and the brown or olive-coloured beds of the Yenangyoung stage at places where the contact between the two is well exposed, as for instance in the Oung-Ban ravine between Kodoung and Twingon. In fact, the results of the deep borings carried out at Twingon render it utterly impossible to assume an absolutely conformable superposition of the Yenangyoung stage on the Prome stage. The study of these sections leads to the assumption that a break must exist between the Upper Prome beds and the lower beds of the Yenangyoung stage, at least in the country near Yenangyoung. On the other hand it deserves to be mentioned that at Yenangyat the Yenangyoung beds rest (apparently with absolute conformity) on the Prome stage.

Although there exists, therefore, a sharp lithological difference between the Prome stage and the Yenangyoung stage—a difference from which one would rather feel inclined to consider the latter as the basal beds of the Irrawaddi division, so great is the lithological similarity between the two—still the palæontological evidence unquestionably proves that the Yenangyoung stage is widely different from the Irrawaddi division and closely related to the Prome stage. It must therefore be included in one series with it.

a. Thickness.

At Yenangyoung the beds composing the Yenangyoung stage form a series of about 1,100 feet in thickness.

At Singu the thickness is about 700 feet, but here the whole series is not completely exposed, and it is impossible to say to what depth it may still extend.

At Yenangyat the whole series is again well seen: its thickness at this place is about 1,200 feet.

It is therefore tolerably certain that, at least in Central Burma, the Yenangyoung stage is only of moderate thickness as compared with the other groups composing the Burma tertiaries.

b. Lithological characters.

The chief constituents of the Yenangyoung stage are soft clays, alternating with beds of sandstone, which may either form thin hard bands, or thicker soft beds. The clay is usually of olive colour, but in various instances, bluish tinges, particularly near Yenangyat, have been observed. One involuntarily imagines a struggle between the bluish colour of the older beds and the olive colour of the newer strata; there are frequent relapses, so to speak, to the original bluish colour, till eventually the olive colour gets the upper hand and bluish tinges have entirely disappeared in the Irrawaddi division. This struggle between the two colours is extremely well seen at Yenangyat, where, after having made a final effort, the bluish colour of the clay disappears with the highest bed of the Yenangyoung stage The sandstone is usually very friable, and of a yellowish colour; bands of hard kidney-shaped or globular concretions occurring very frequently.

A most remarkable feature is the presence of gypsum, which occurs frequently in large crystals in the clayey beds. It is noticeable that no gypsum is found either in the lower Prome stage or in the Upper Irrawaddi division, and in this respect its occurrence forms an exceedingly useful feature for the recognition of the Yenangyoung stage. One may be almost certain to have beds of the Yenangyoung stage under observation when the gypsum is noticed.

c. Palæontological characters.

Fossils are rather scarce in the Yenangoung stage, that is to say, the localities in which they are found are not numerous; but when present the fauna is usually a rich one. So far I have discovered three places where fossils have been found, and every one of these localities unquestionably represents a different horizon.

The lowest horizon is probably represented by beds which contain a very rich fauna near Minbu. In a similar horizion, fossils also occur at Yenangyat, but I never found at this place a bed where they were recognizable, being in every case mostly fragments.

Next in the series follows the *Cypricardia* bed of Singu.

The last in the series is the *Batissa* or *Cyrena* bed containing countless numbers of the two species *Batissa* (*Cyrena*) *crawfurdi* and *petrolei*. It will be useful to discuss the palæontological characters of each of these beds separately, and eventually compare the whole of the fauna with that of the Prome stage.

1. MINBU-BED.

The fauna of this bed, which is well exposed at the hill, north of the mud-volcanoes, has been described by me in the memoir previously quoted. So far the following species have been found:—

1. *Paracyathus cæruleus*, Duncan.
2. *Ostrea*, sp. 1.

3. *Pecten* cf. *favrei*, d'Arch. & Haime.
4. *Nucula alcocki*, Noetling.
5. *Venus* sp.
6. *Tellina kingi*, Noetling.
7. *Corbula* spec. nov.[1]
8. *Trochus buddha*, Noetling.
9. *Trochus blanfordi*, Noetling.
10. *Solarium affine*, Sowerby.
11. *Solarium cyclostomum*, Menke.
12. *Scalaria birmanica*, Noetling.
13. *Scalaria irregularis*, Noetling.
14. *Scalaria subtenuilamella*, d'Arch. & Haime.
15. *Turritella affinis*, d'Arch. & Haime.
16. *Calyptræa rugosa*, Noetling.
17. *Natica obscura*, Sowerby.
18. *Natica callosa*, Sowerby.
19. *Cerithium* sp.
20. *Strombus nodosus*, Sowerby.
21. *Cypræa granti*, d' Arch. and Haime.
22. *Cassis d' archiaci*, Noetling.
23. *Cassidaria dubia*, Noetling.
24. *Cassidaria minbuensis*, Noetling.
25. *Triton* (*Simpulum*) *davidsoni*, d'Arch. & Haime.
26. *Triton pardalis*, Noetling.
27. *Ranella tubercularis*, Lamark.
28. *Nassa cautleyi*, d' Arch. & Haime.
29. *Clavella djocdjocartæ*, K. Martin.
30. *Fasciolaria nodulosa*, Sowerby.
31. *Murex arrakanensis*, Noetling.
32. *Volvaria birmanica*, Noetling.
33. *Voluta dentata*, Sowerby.
34. *Oliva djocdjocartæ*, Martin.
35. *Terebra fuscata*, Brocchi.
36. *Pleurotoma voyesi*, d'Arch. & Haime.
37. *Pleurotoma* (*Drillia*) *interrupta*, Lamark.
38. *Pleurotoma yenanensis*, Noetling.
39. *Conus* (*Rhizoconus*) *mallacanus*, Hwass.
40. *Balanus sublaevis*, Sowerby.
41. *Callianassa* sp.
42. *Lamna* sp.
43. *Myliobates* sp.
44. *Carcharias* (*Prionodon*) sp.

The above list shows that the Minbu bed contains nearly the same number of species as the Prome beds and that out of a total of 44 species it contains 29 species which are common to both faunas. So far the forms peculiar to the Minbu bed are the following :—

1. *Ostrea* sp. 1.
2. *Venus* sp.
3. *Solarium cylostomum*, Menke.
4. *Scalaria birmanica*, Noetling.
5. „ *irregularis*, Noetling.
6. „ *subtenuilamella*, d' Arch. & Haime.

[1] Described as *Corbula harpa*, d'Arch. & Haime.

7. *Cerithium* sp.
8. *Strombus nodosus*, Sowerby.
9. *Cassis d'archiaci*, Noetling.
10. *Triton (Simpulum) davidsoni*, d'Arch. & Haime.
11. *Triton pardalis*, Noetling.
12. *Volvaria birmanica*, Noetling.
13. *Terebra fuscata*, Brocchi.
14. *Pleurotoma voyesi*, d' Arch. & Haime.
15. *Myliobates*, sp.

Of these 15 species 4 have been only generally determined, 4 are new forms and the remainder of 5 species have been previously described. Of these the following three species are found in the Gaj group :—

Scalaria subtenuilamella, d'Arch. & Haime.
Strombus nodosus, Sowerby.
Triton (Simpulum) davidsoni, d'Arch. & Haime.

in the Nari group occur—

Solarium cyclostomum, Menke.
Triton davidsoni, d' Arch. & Haime.

recent is—

Solarium affine, Menke.

of uncertain geological horizon is—

Pleurotoma voyesi, d'Arch. & Haime.

while the last one—

Terebra fuscata, Brocchi.

occurs in the Upper Miocene of Europe.

I do not think that the above meagre list is in itself sufficient to decide the question of the age of the Minbu bed; if any inference could be drawn, it would be that it shows almost a larger number of species found in the Gaj group of Western India than the Yenangyat fauna. It may, perhaps, be possible that its actual horizon is a little lower down in the series than I have here assumed, and that it ought to be included in the Prome stage, although this would not materially alter the views here promulgated regarding the position and age of the Yenangyoung stage. I have assumed from its position in the series above the petroliferous horizon, which, so far as we know for the present, seems to be a very excellent one, that it is younger than the Yenangyat fauna; but of course it is extremely difficult, owing to the monotonous development of the tertiary strata, absolutely to correlate certain beds of two localities, which are at some distance from each other.

That there exists a difference between the two faunas cannot be denied, if we look through the above list; this difference may only represent the local variation of one and the same fauna, or it may really represent a difference in the geological age of the two faunas. For the present this question must be left undecided, as our imperfect knowledge of the tertiary fauna in Burma does not allow such intricate questions as the above to be settled; but my opinion is, that the Minbu fauna holds a position at the base of the Yenangyoung stage, and I have therefore included it in the discussion of this group. Should it, however, eventually be found better to include the Minbu-bed in the Prome stage, it must not be disregarded, that it certainly occupies a higher horizon than the Yenangyat beds.

2. *Cypricardia*-BED.

The geological position of this bed is much more accurately fixed with regard to the Yenangyat bed, than that of the Minbu bed. The Yenangyoung stage has been traced from Yenangyat down to Singu, and it is quite certain that at Singu only the higher beds of the Yenangyoung stage are exposed.

The Cypricardia bed holds a position comparatively close to the upper boundary of the Yenangyoung stage, and it must therefore be decidedly younger than either the Minbu or Yenangyat fauna. It is an argillaceous sandstone containing numerous lumps of hard clay, which, strange to say, are almost in every case perfectly riddled by the borings of a *Lithodomus*. Its thickness is not more than 6 inches, but it forms a most constant horizon, which can be easily recognized at either side of the anticline. It is probably from this bed that the late Dr. Oldham obtained some fossils, when visiting Singu in 1855.[1] Unfortunately this fauna has not been carefully examined yet, because it was only during the field season 1894-95, that I discovered the *Cypricardia* bed, but still the knowledge of the species occuring in the Yenangyat and Minbu beds has enabled me to identify some of the species occurring in it, while other forms were recognised as being absent in the abovenamed beds. The entire character of the fauna of the *Cypricardia* bed is totally different from that of either the Yenangyat or Minbu beds. While in the former the *Gastropoda* predominate—out of a total of 69 species, 45 belonging to the *Gastropoda*—it is certain that in the Cypricardia bed the *Pelecypoda* predominate not only by number of species, but also by number of individuals. The commonest forms are an *Ostrea* sp., *Pecten cf. favrei* d'Arch. and Haime, and a *Cypricardia*, besides *Paracyathus cæruleus*, Duncan. It is, however, strange that, although the *Ostrea* sp. is the commonest form, not a single well-preserved specimen could be obtained. *Pecten cf. favrei*, d'Arch. and Haime, is always well-preserved like the other Pelecypoda, and I dare say that the question whether it really represents the Indian species can now be settled; next in frequency is a beautifully preserved *Cypricardia*, and an *Avicula*, and then comes the easily recognizable *Paracyathus cæruleus*, Duncan. The following is a provisional list of the fossils, which I have been able to recognize; but I wish at once to state that this list is by no means exhaustive.

1. *Paracyathus cæruleus*, Duncan, very common.
2. *Ostrea*, sp. apparently related to *Ostrea*, sp. 1, from Minbu; very common.
3. *Pecten cf. favrei*, d'Arch. and Haime, very common.
4. *Modiola*, sp. 1, rare.
5. *Modiola*, sp. 2, rare.
6. *Lithodomus* sp., very common.
7. *Avicula* sp., very common.
8. *Daphoderma caelata*, Reeve (*Arca burnesi*, d'Arch. and Haime; common).
9. *Venus*, sp. 1, the same as found at Miabu; very common.
10. *Venus*, sp. 2, rare.
11. *Tellina* (*Tellinella*) *hilli*, Noetling; rare.
12. *Tellina kingi*, Noetling; always beautifully preserved, but not common.
13. *Trochus sp., cf. blanfordi*, Noetling; common.
14. *Solarium affine*, Sow.; rare.

[1] Yule, mission to the Court of Ava, p. 27, and Appendix A, page. 319.

15. *Conus* (*Rhizoconus*) *mallacanus*, Hwass; rare.
16. *Conus* (*Leptoconus*) *marginatus*, Sowerby; rare.
17. *Callianassa* sp. nov. The hands of a gigantic *Callianassa* sp. are not very rare.

To judge from this specimen it seems that the isolated fragment of a finger which I referred to *Pagurush* [1] really belongs to this gigantic *Callianassa*. As I have remarked above, this list is by no means an exhaustive one, and a careful examination of my collection will swell its number considerably; but it may be stated at once, that almost all the forms, which have been recognized hitherto, are identical with those described from the Yenangyat and Minbu beds. On the other hand some new forms, which had hitherto not been found in either of the abovenamed beds, have been discovered; the most conspicuous among these are—

Avicula sp.
Cypricardia sp.

besides various others.[2]

The geological horizon of the *Cypricardia* bed being decidedly higher up in the series than either of the fauna abovementioned, it is almost certain that the faunistic difference noted cannot be considered as only a local variation.

3. *Batissa*-(*Cyrena*-) BED.

The highest position in the Yenangyoung stage is occupied by a bed which is unfossiliferous almost throughout its whole extent, but containing at two places at least in the neighbourhood of Minlindoung, countless numbers of *Batissa crawfurdi* Noetling and *Batissa petrolei* Noetling. These two forms are also found in the next higher bed, which most decidedly belongs to the Irrawaddi division, and they form the connecting link with that series of strata which contain such an entirely different fauna from that of the older tertiaries.

If the *Cytherea promensis*, a species established by Mr. Theobald, but neither described nor figured, is, as I suppose, identical with either *Batissa crawfurdi* Noetling or *Batissa petrolei*, Noetling, we are bound to assume that this form occurs far down in the tertiary series of Lower Burma. The question is an interesting one, but it can only be decided after the examination of Mr. Theobald's collections. In Upper Burma the *Batissa* bed concludes the Yenangyoung stage, and if we assume that this horizon would be the same in Lower Burma, the logical consequence would be that the Yenangyoung stage is much thicker in Lower Burma and that on the top of the *Batissa* bed there exist several fossiliferous horizons, which are not represented in Upper Burma.

These are, however, views which can only be settled by actual observation in the field, as I do not think that the examination of Mr. Theobald's collections will shed much light on this question, as the positions of the horizons in which the fossils were collected are not always known with certainty with reference to each other.

I may conclude the description of the palæontological features of the Yenangyoung stage with the remark that, to my knowledge, no fossil wood either car-

[1] Memoir, Geological Survey of India, Vol. XXVII, part. I, page 44.

[2] I hope that I shall soon be able to give an exhaustive description of this fauna which, from its geological position, has a particular interest.

c. Palæontological characters.

The Irrawaddi division is undoubtedly the most interesting in the whole series of the Burma tertiaries owing to the fact that it contains numerous remains of terrestrial and fluviatile animals. It is, however, an open question whether these remains are generally distributed throughout the group, or whether they are restricted to certain localities only. It seems to me that there is no reason why they should not be found anywhere, whenever the strata of this group are exposed, but so far as my experience goes they are much more frequent at certain localities than at others.

For instance, along the river shore from Nyounghla to a few hundred yards north of Sithabwé village fossil bones are extremely common; further north they become scarce, and north of Yenangyoung I have not yet found a single specimen, although the beds developed in this part are the same as those south of Yenangyoung village. Near Pagan I have searched for miles along the bank of the Irrawaddi, where the Irrawaddi division is well exposed, without finding a single specimen.

It is further very remarkable that not only were the first fossil bones which came from Burma, and which were described by Dr. Buckland as early as 1823,[1] collected near Yenangyoung, probably at the very locality which I mentioned above, but that also the chief collection of fossil bones which was made by the members of the Mission to Ava, was found near Yenangyoung.[2] To judge from a remark made by King Mindon Min in the most interesting conversation recorded on pages 112 and 113 of Yule's Mission to Ava, "Biloos" bones[3] are very common in the Yaw country, and it is quite possible that the list which Mr. Theobald gives[4] as coming from "Ava" refers to fossils collected in the Yaw country. They certainly cannot come from Ava, as nowhere in the neighbourhood of that town do beds of the Irrawaddi division occur.

Mr. Theobald expressly states that in Lower Burma the fossil wood group is only locally mammaliferous, and if we thus take all the evidence we must believe that the fossil bones are only of frequent occurrence at certain localities, of which three are known at the present time, *viz.*:—

1. Lema, near Thayetmyo in Lower Burma.
2. Bank of the Irrawaddi between Nyounghla and Yenangyoung.
3. Yaw-country.

Of these three localities, I know only the second from personal experience; as regards the first, we have the evidence of Mr. Theobald, and as regards the third, I must say that all the probabilities are in favour of the occurrence of fossil bones, because the very strata in which they have been found near Yenangyoung are largely developed in the broad valley of the Yaw. On the other hand, I must say that this is no absolute proof, for although the Irrawaddi division is largely developed in Northern Burma, as for instance, in the Pakôkku, Upper Chindwin, Ye-u and Shewbo Districts, yet I have not found a single specimen of a fossil bone, although I repeatedly and carefully searched for them. I may have overlooked them, a possibility which I fully admit, and future researches may discover them in

[1] Transactions of the Geol. Soc., Series II, Volume II, page 377.
[2] Narrative of the Mission to the Court of Ava, 1858, page 315.
[3] Biloo, a fabulous monster.
[4] Op jam. cit., p. 07.

parts where I have looked in vain, but for the present we must content ourselves with stating that the locality in Upper Burma where fossil bones have been found in largest numbers is the country around Yenangyoung.

The seemingly erratic manner of horizontal distribution of the fossil bones might perhaps be explained if we assume that they are restricted to a certain portion of the strata of the Irrawaddi division, and that they are therefore only found at places at which that particular portion is well exposed.

The question is a difficult one to decide, and would require further observations, but if one may be allowed to draw a conclusion from the occurrence of the fossil bones around Yenangyoung it seems that they are restricted to the lower and middle parts of the Irrawaddi division, while they are extremely rare, if not entirely wanting, in the upper part, being replaced by the frequently occurring fossil wood. This supposition would explain the curious mode of occurrence near Yenangyoung the youngest strata of the Irrawaddi division being chiefly exposed along the river bank south of Nyounghla and north of Yenangyoung.

The late Dr. Oldham[1] had already observed that the fossil bones are chiefly found in the ferruginous conglomerates and "breccia or conglomerate" which he has found at Minlindoung[2] and which is considered by me as the bottom-bed of the Irrawaddi division, and distinguished as a special bone-bed, of which more will be said later on. Besides this bed, I found fossil bones at several higher horizons, and I think that I am able to recognize certain well marked horizons characterised by their vertebrate fauna; this sub-division will be discussed presently.

As regards the fauna, which has left its remains deposited in the Irrawaddi beds, the following species and genera have been noticed by various authors. The first to determine the collection made by Mr. Crawford was Dr. Buckland, who recognised the following species:—

Mastodon latidens, Clift.
" *elephantoides*, Clift.
Hippopotamus sp.
Rhinoceros sp.
Sus sp.
Tapirus sp.
Bos sp.
Cervus sp.
Antelope sp.
Crocodilis sp. *aff. vulgaris.*
Leptorhynchus sp. (*Garialis* sp.)
Trionyx sp.
Emys sp.

The specimens collected by Dr. Oldham, of which he has given a rough list at the end of his paper, have subsequently been more accurately determined, and I suppose that the list of fossils from Ava which Mr. Theobald gives[3] refers to them. The following species and genera are enumerated:—

Mastodon latidens, Clift.
Elephas cliftii, Cautl. and Falc.
Mastodon elephantoides, Clift.

[1] Mission to Ava, page 315.
[2] Dr. Oldham spells the word Menleng.
[3] Op. jam. cit., p. 67.

7. *Sus titan.*
8. *Hippotherium antelopinum.*
9. *Gavialis sp. cf. gangeticus.*
10. *Emyda palæindica.*
11. *Colossochelys atlas.*

That is to say, all such forms as have been specifically determined, except those of course which are indigenous to Burma. Out of the remaining 15 species, two, *viz.*—

1. *Hippopotamus irravadicus.*
2. *Vishnutherium irravadicum.*

are indigenous to Burma, while the remaining 13 species have for the present been only generally determined.

The proportion of species identified with Siwalik forms is therefore, if we disregard the two indigenous species, about 50 per cent. of the total or much larger than Mr. Oldham supposed it to be.[1] In fact, I have not the slightest doubt that the proportion will be still greater once the fauna has been carefully studied, there being certainly among the 13 species hitherto only generally determined some which will be found identical with Siwalik forms.

On the other hand it cannot be denied that as regards the general character of the fauna of the Irrawaddi division, it exhibits some features decidedly different from the Siwalik fauna. The *Ungulata*, although being in the majority, are represented by a much smaller number than in the Siwalik fauna, but the most striking feature is the remarkable scarcity of *Carnivora* of which only two species have so far been discovered in the Irrawaddi division, which contrasts strongly with the large number of species in the Siwaliks. I am, however, not prepared to state that these differences are absolute, my opinion is rather that once the Irrawaddi division is more explored, and we know its fauna to a larger extent, the discrepancy between the total number of species on one side, and the remarkable difference of the development of the *Carnivora* in both regions will disappear, or at least become smaller.

For the present we must content ourselves with having pointed out that notwithstanding its smaller number of species the fauna of the Irrawaddi division must be considered as correlative to that of the Upper Siwaliks.[2]

Luckily in Burma we are in a much better position for ascertaining the age of the Irrawaddi division than were the Indian geologists, when fixing the age of the Siwaliks; as previously pointed out, the Irrawaddi division rests conformably on beds of miocene age. The natural conclusion is therefore that the Irrawaddi division represents the Pliocene of Europe, a supposition which is fully in accordance with the views lately promulgated by Mr. Oldham in the second edition of the Manual of the Geology of India, according to which "it is impossible to deny that the balance of evidence is in favour of a Pliocene age." In fact we might rather say that the evidence of the fauna of the Irrawaddi division is a further strong proof of the Pliocene age of the Siwaliks, for it would be impossible to assume that the Irrawaddi division was of Upper Miocene and not of Pliocene age. Such an assumption would simply mean a perversion of all facts and a negation of the natural divisions of the Tertiary rocks in Burma.

[1] Manual of the Geology of India, 2nd edition, page 341.

[2] Mr. Lydekker, when describing the fauna of the Siwaliks, never seems to have doubted this, for the specimens collected in Burma are included among his list of the Siwalik species.

Besides its fauna the Irrawaddi division is distinguished by an abundance of fossilized wood. In fact the fossilized wood has attracted the attention of travellers in Burma more than anything else with the exception perhaps of the occurrence of rubies. There is hardly a book dealing with Burma in which reference is not made to the fossil wood, and the quaintest theories have been set forth to explain its presence in such abundance. It is, however, strange to say that although quantities of it must have been brought to England since the end of the last century no scientific examination of it has hitherto been made.

The fossil wood is distributed throughout the whole of the Irrawaddi division, but I am unable to say whether there is any rule as regards its vertical distribution. Frequently enormous logs may be seen imbedded in the strata. I noticed a specimen of about 60 feet in length, east of Yenangyoung, broken into several pieces by its mere weight, but still partly imbedded in the soft sandstone. Pieces of smaller size are of course extremely common, and cart loads might be picked up in a few hours.

There are two modes of petrification, the one in which the wood fibre has been replaced by silica, the other in which it has been replaced by hydroxide of iron. The former is the common one; the latter has been only observed in a few cases of drift-wood imbedded in the ferruginous conglomerates.

The question as to how this wood became fossilized has of course occupied the attention of more than one observer, but it cannot be said that a satisfactory explanation has hitherto been given.

Mr. Theobald having observed that the fossil wood when found *in situ* never exhibits any signs of being rolled or otherwise worn away, nor gives any other indications of transport, therefore assumes that the wood could not have been in a petrified state prior to being embedded in its present position. He therefore supposes that petrification took only place after the trees had found their present resting place, an assumption which he explains by the following quaint theory. He supposes that the trunks of trees floated about till water-logged in shallow lakes, in which, on sinking, they became mineralised through the agency of springs holding silica in solution.

The logical outcome of this theory is, that wherever a single specimen of a silicified log is found *in situ*, we are bound to suppose that just underneath that very log, a spring rose, in order to petrify it, and, having done its work, disappeared without leaving behind it any other traces of its activity. The absurdity of such a theory is too evident, and no more need be said about it, but in discarding one theory one ought to be able to replace it by a more satisfactory one. I must, however, confess that in matters of this kind, which are chiefly of a chemical nature, I am unable to give a satisfactory solution. I was therefore extremely glad to find that Dr. Irving has propounded a theory regarding the origin of the silicified wood in the Pliocene of the Libyan desert [1] which might be equally well applied to the silicified wood of Burma. I cannot therefore do better than give Dr. Irving's own words, which are as follows:—

"Remarking on the silicification of wood, he wished again to emphasize the difference in the action of carbonic acid in petrological changes, according as it

[1] Quart. Journ. of the Geol. Soc., 1894, volume L., page 547.

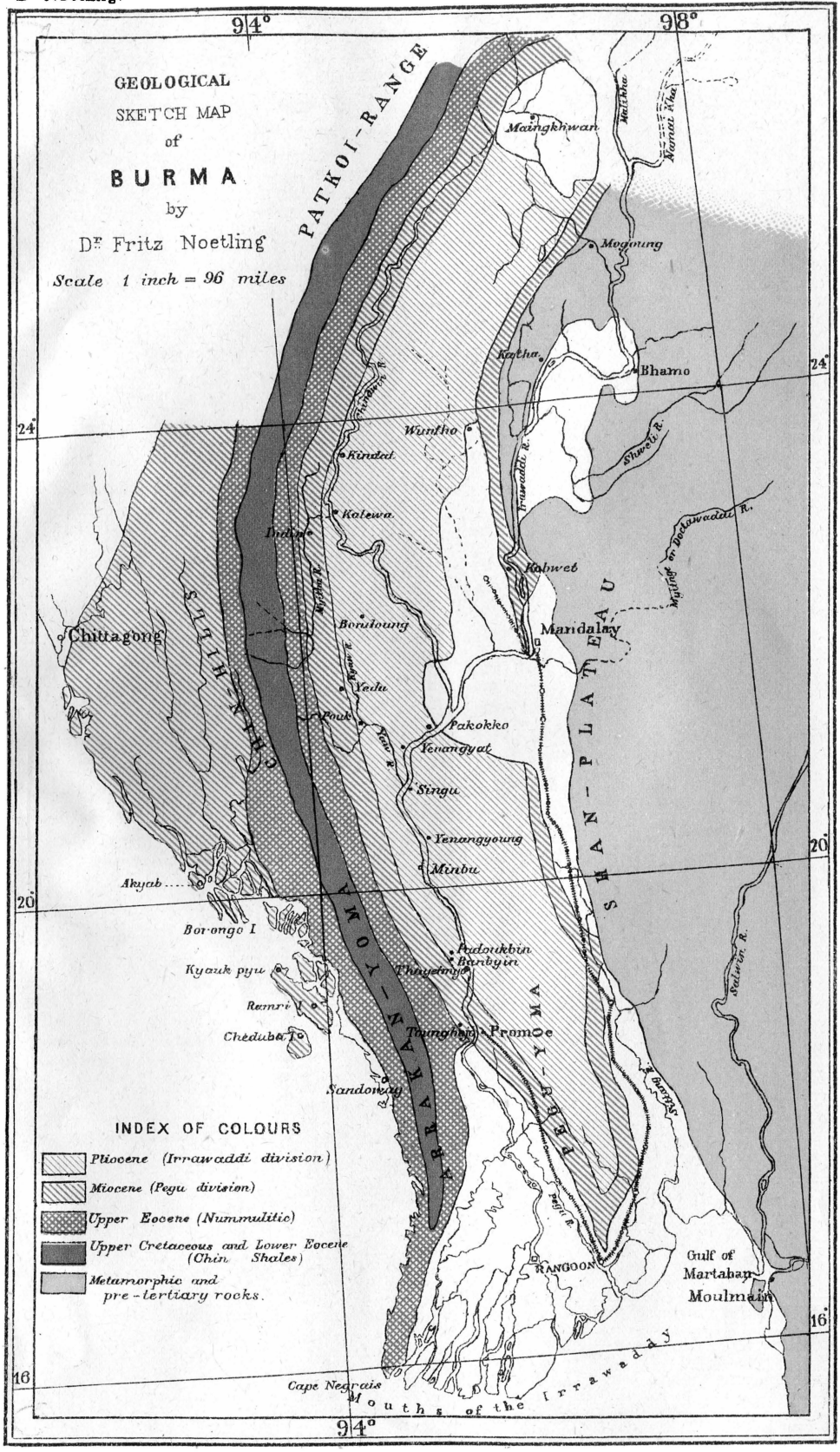
Burma Tertiaries, with the names given to each subdivision; these are arranged in such a way that at a glance it may be seen what principles have guided me:—

Character of fauna.	Name of Series.		Character of Deposits.	Character of sediments.	Name of division.	
Terrestrial and Fluviatile.	Burma series.		Deltaic.	Yellow sandstones, olive-coloured clays, ferruginous conglomerate; no gypsum.	Irrawaddi division.	
Marine	ARRAKAN SERIES.	Upper.	Littoral and Estuarine.	Yellow sandstone, olive coloured and bluish clay; gypsum.	Yenangyoung stage.	Pegu division.
				Grey sandstone, bluish clay.	Prome stage.	
		Lower.	Littoral	Limestone, grey sandstone, bluish clay.	Nummulitic division.	
			Deep sea	Shales	Chin shales.	

In concluding this sketch of the Burma Tertiaries, the following table will convey my views as to the correlation of the Tertiary strata in Burma, India and Europe. It would, of course, be useless to attempt anything beyond a general comparison, and, I think, we must be satisfied if we recognize with some certainty the large sub-divisions of the European Tertiaries in distant Burma.

The Tertiaries of India, of which those of Burma form only the eastern continuation, exhibit, by their remarkable division into two large groups differing widely in the character of their respective faunas, such peculiarities that any correlation with the Tertiary rocks of Europe, except one based on the broadest lines, is almost impossible, a fact which has already been noted by Dr. Blanford.

Europe.	Burma.				Western India.	Himalaya, North-West area.	Himalaya, Simla area.
Pliocene.	Burma Series.			Irawaddi division.	Manchhar group.	Upper Siwaliks.	Upper and middle Siwaliks.
Miocene	ARRAKAN SERIES.	Upper.	Pegu division.	Yenangyoung stage.	Gaj group	Lower Siwaliks.	Nahan beds Lower Siwaliks.
				Prome stage.	Nari group	Murree beds	Kasauli group.
Eocene		Lower.		Nummulitic division.	Kirthar group	Upper and Lower Nummulitic.	Dagshai and Subathu group.
				Chin shales	Ranikot group	?	?


GEOLOGICAL
SKETCH MAP
of
BURMA
by
Dr Fritz Noetling
Scale 1 inch = 96 miles
94°
98°
24°
20°
16°
PATKOI-RANGE
ARAKAN-YOMA
SHAN-PLATEAU
PEGU-YOMA
Maingkhwan
Mogoung
Katha
Bhamo
Wuntho
Kindat
Kalewa
Kabwet
Mandalay
Chittagong
Bonduong
Yedu
Pauk
Pakokku
Yenangyat
Singu
Yenangyoung
Minbu
Akyab
Bor-ongo I
Kyauk pyu
Ramri I
Cheduba I
Padoukbin
Thayetmyo
Prome
Sandoway
Tounghoo
RANGOON
Gulf of
Martaban
Moulmain
Cape Negrais
Mouths of the Irrawaddy
INDEX OF COLOURS
Pliocene (Irrawaddi division)
Miocene (Pegu division)
Upper Eocene (Nummulitic)
Upper Cretaceous and Lower Eocene (Chin Shales)
Metamorphic and pre-tertiary rocks.